

# **Very High Resolution Imaging Diver Held Sonar**

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## **LONG-TERM GOAL**

The long-term goal has two parts. The first is to evaluate the feasibility and usefulness of a high resolution fixed focus single beam manually scanned sonar. And, the second is to evaluate the buried target detection capabilities obtainable with the same design. If these capabilities prove valuable, they can be incorporated into the following three systems currently under development:

- The diver held Integrated Navigation and Sonar System (INSS) for the Very Shallow Water (VSW) Mine Countermeasures (MCM) Detachment.
- The Under Water Imaging System (UIS) for Explosive Ordnance Disposal (EOD) operations.
- The Hydrographic Littoral Mapping Device for Naval Special Warfare (NSW) operations.

## **OBJECTIVES**

The objective is to develop new transducers and lenses with fixed focal lengths for the INSS diver held sonar. The largest of these will allow a VSW diver to obtain a very high-resolution sonar image (with approximately 1" by 1" resolution at a range of 15 feet) and to obtain lower resolution images of buried targets. The current resolution with the existing INSS transducer is 1" by 6" at a range of 15 feet (which is really only sufficient for gross imaging of target features) and the current INSS sonar provides no buried mine detection capability. With these new focused transducers (which will replace the existing INSS transducer), or lenses (which will simply be placed over the existing transducer) the diver should obtain identification quality sonar images of mines while at a safe standoff distance that corresponds to the focal length of the transducer / lens. This will eliminate the need (in most cases) for the diver to see/touch the mine for target identification. With the proposed resolution, features such as bolt patterns, lifting eyes, and arming plates should be visible. A second characteristic of these new transducers is that they will be sufficiently broad band to allow operation at very low frequencies. This lower frequency operation will allow the sonar sound to propagate through the bottom and thereby, allow lower resolution imaging of buried targets.

## **APPROACH**

This effort can be divided into 6 portions, all of which will be overseen by Dr. Keith Lent.

1. The first portion of this project will consist of the design and construction of a test transducer and three lenses. The transducer will be constructed from a 1-3 composite piezo-ceramic material using standard transducer construction techniques. This transducer will contain electrical jumpers that will allow portions of the transducer to be switched on and off, thereby adjusting the aperture of the transducers (the full aperture is 24"). The transducer will have a focal length of 15 feet. The three lenses will be simple cylindrical lenses machined out of a flat sheet of acrylic. Mechanical engineers and technicians here will do the detailed mechanical design and construction of these transducers.
2. The second portion of this project will consist of the modification and testing of the software in the INSS system to support the high resolution and buried target imaging. This software will be written on a standard notebook computer and then downloaded into an INSS system for testing.
3. The third portion of this program will be the test and evaluation of tradeoffs between the various adjustable parameters in the transducers in a working INSS system. These tests will be done by evaluating the sonars performance with the various parameter configurations in ARL:UT test tanks, the Lake Travis Test Station facility, and in a more realistic environment (most likely the VSW-MCM detachments mine field in San Diego). Some tests / evaluations will be conducted using VSW-MCM, EOD and NSW divers. They will be able to contribute valuable feedback on the acceptability / usability of these transducers for their various missions. The goal of this portion will be to determine the optimal parameters for the final design of the transducer and/or lens. During these tests both proud and buried mines as well as other test targets will be used.
4. The forth portion of this project will consist of the construction of a final transducer and/or lens with the optimal size and focal length parameters determined during the previous evaluation.
5. The fifth portion will consist of verification and demonstration of the final design in a realistic environment using VSW MCM detachment divers.
6. The final portion will consist of writing a report documenting the design, the tests conducted, and the performance results.

## **WORK COMPLETED**

The design and construction of three lenses and one test transducer has been completed. The three lenses are each 8 inches wide by 2 inches tall and are designed to be placed in front of the existing INSS transducer. They are designed to focus at 5', 10' and 15' and should provide better than 1" x 1", 1" x 2" and 1" x 3" resolutions respectively. The test transducer is a fixed focus transducer with a 24" aperture focused at 15'. It should provide better than 1" x 1" resolution.

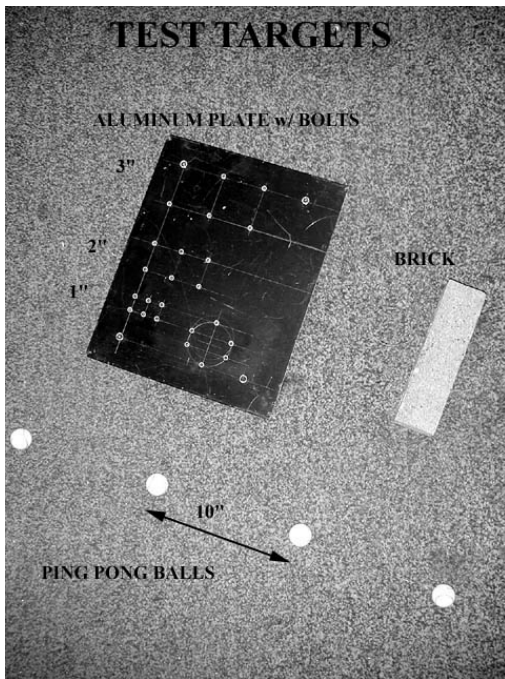
The software for an INSS sonar has been modified to provide a zoom window in which the high resolution imaging can be viewed. It has also been modified to provide a low frequency mode of operation for detecting/imaging buried targets.

The initial in water tests of the lenses and test transducer have been completed. Sonar images have been recorded of test targets and mine simulators. Also, images have been recorded of test targets both proud and buried in sand to ~1" depth.

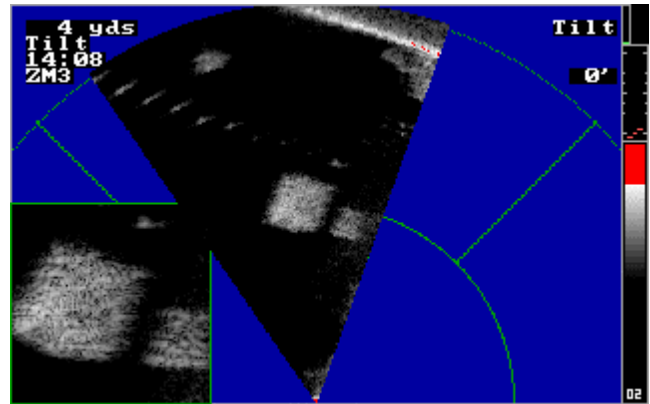
Divers from the VSW-MCM detachment, EOD and NSW are expected to dive and evaluate this prototype hardware in early October 2000. They will then be asked to provide feedback to help determine the optimal choice of design parameters for the final design.

## RESULTS

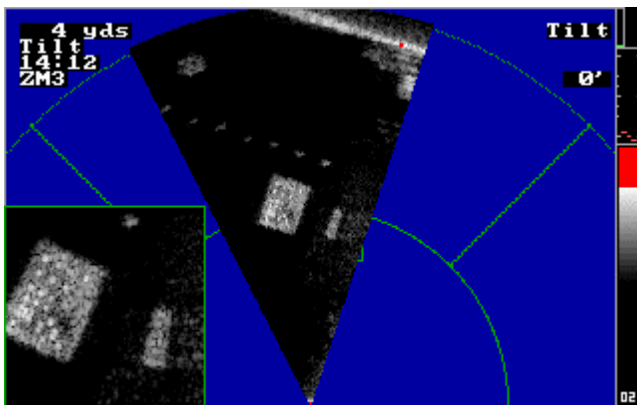
The 24" aperture, 15' focal length test transducer and three lenses have been constructed and testing has begun. The results have been very successful. The achieved focal resolution matched the theoretically predicted resolution, and no significant lens imperfections or impedance mismatch related distortions were seen. What this means is that when the lens designed to focus at 5' is used the resulting image resolution is slightly better than 1"x1". This means that 1/8" bolt heads placed 1" apart can be resolved. A test target consisting of a 17"x14" aluminum plate was constructed to verify this resolution. It has a number of bolts placed at 3", 2" and 1" spacings. It also has a 6-bolt circular pattern to simulate an electronics housing cap that could be similar to a mine/bomb access plate. A photograph of this target, along with a brick and a string of Ping-Pong balls is shown in the Figure 1. Figure 2 shows an INSS sonar image of the same three targets with the zoom mode enabled, but without any lens or focusing. The zoom mode window, which appears in the lower right corner of the display, is an enlarged view of the sonar data at the center of the main display. Note; at the far edge of the image the wall of the test tank is also visible. This image shows the resolution of the existing INSS sonar. The plate and brick and Ping-Pong ball string are recognizable as separate objects but they are clearly blurred out. The INSS resolution (unfocused) is about (1"x8"). Notice that the brick has been smeared out horizontally to appear almost square. Figure 3 shows the exact same scene with the only change being that a lens has been snapped on to the front of the INSS sonar. The lens is designed to focus at 5'. As before the plate and brick are enlarged in the zoom window, but in this image the bolts have become visible and the edges of the brick and the plate are much sharper. Figure 4 shows an even greater zoomed (enlarged) image of the same plate (note the Ping-Pong ball string has been moved). In this image only the lower half of the plate is seen in the zoom window and the brightness has been decreased from the previous image. All of the bolts even those 1" apart are resolvable.



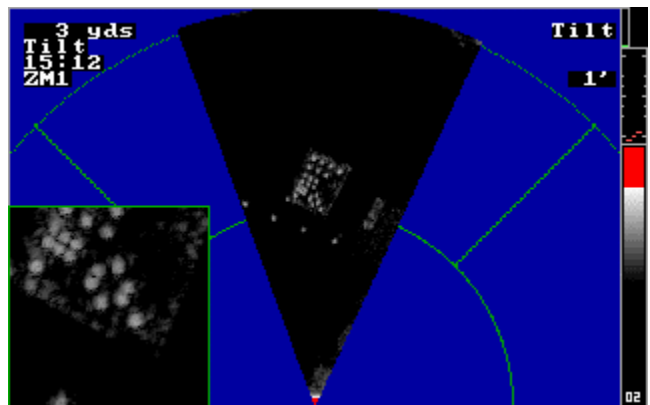
*Figure 1. Photo of Test targets*



*Figure 2. Unmodified INSS sonar image of test targets*

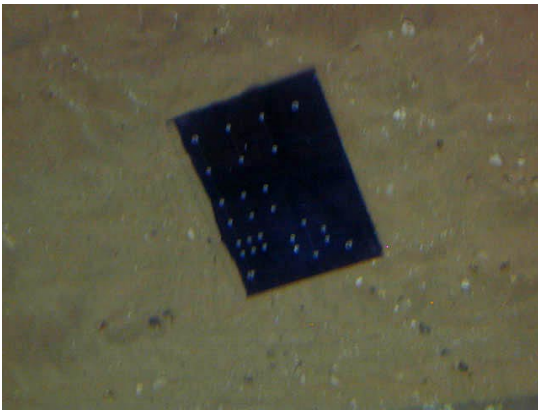


*Figure 3. Image with 5' focus lenses*

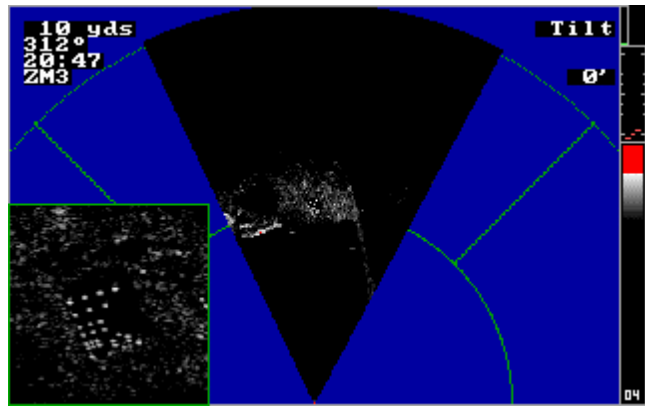


*Figure 4. Greater zoom image w/ 5' focus lens*

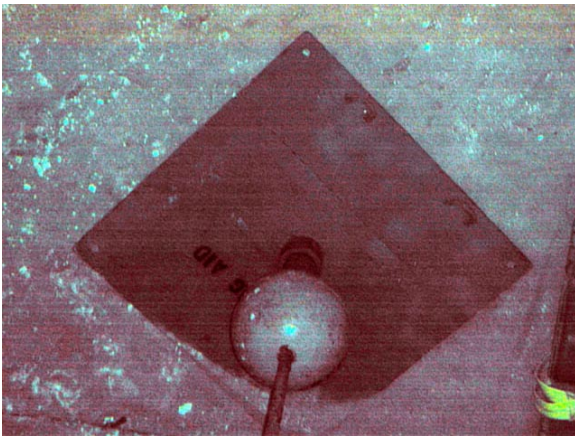
Next tests were done with the 24" aperture fixed focused transducer, focused at 15'. Figure 5 shows a picture of the test target lying on a sandy bottom 15' away from the sonar. Figure 6 shows the sonar image obtained with the INSS sonar with this new transducer. All of the bolts can be resolved on the plate. This demonstrates that the INSS sonar combined with this transducer has at least 1" x 1" resolution at 15'.



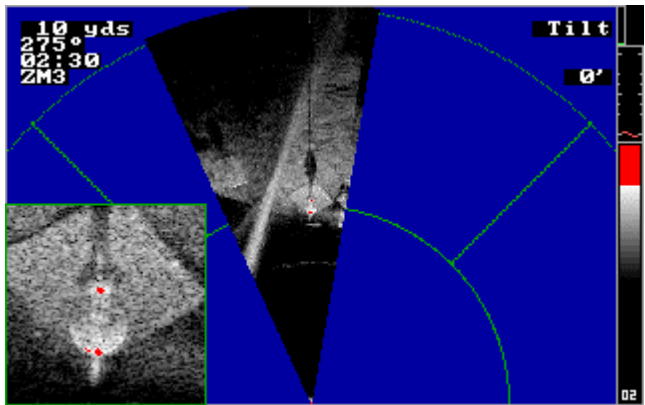
*Figure 5. Photo of test target on sand*



*Figure 6. Sonar image using 15' fixed focus transducer*



*Figure 7. Mine simulator on sandy bottom*



*Figure 8. Sonar image of mine at 15' range*

Tests have also begun which consist of imaging mine simulators. Figure 7 shows a photograph taken of a mine simulator that was placed on a sandy bottom. Figure 8 shows the sonar image of this target obtained with the fixed focal length transducer at 15' from the sonar. The rod that protrudes from the top of the mine is approximately 1" in diameter, and the rod, ball, mount and base plate are all clearly visible. The base plate is approximately a 2' x 2' square. In this particular sonar image the brightness has been turned up so that the shadow cast on the sandy bottom is visible.

Tests with buried targets have also begun. The tests done to date consist of imaging a row of Ping-Pong balls (test targets) in normal and buried (low frequency) modes. Four of the Ping-Pong balls were not buried, one was partially buried and one was about 1" below the bottom buried in clean sand. At the normal sonar operating frequency only the non-buried Ping-Pong balls could be detected. But, using the low frequency mode of operation all of the Ping-Pong balls were detected. The echo level from the buried ball was about 7dB lower than the rest. Initial attempts to choose the optimal frequencies for buried mode operation are being conducted and future work will include burial of larger and more realistic targets at deeper depths.

## **IMPACT/APPLICATION**

The high resolution imaging target identification capability will provide a significant reduction in risk to the VSW MCM divers, who currently have to swim up and see/touch mine-like targets for identification in turbid water. The buried target detection capability is also very beneficial to these divers and EOD divers who must locate and ID buried targets that have been found but not identified by marine mammal systems and/or larger low frequency mine hunting ship board sonars. Currently, the only way for a diver to confirm the presence of a buried target is by digging or probing with sticks into the bottom. However, since the marine mammal marks and/or large ship sonar marks are often only accurate to a few yards, it is a tedious and often dangerous process to find and confirm a buried mine mark. It is important to note that this capability will be valuable even though the buried target detection will likely work well only at short ranges, i.e., for detecting buried targets within ~10 to 20 yards.

## **TRANSITIONS**

If these transducer and/or lens designs provide sufficient added value to VSW MCM, EOD or NSW divers, then they can be transitioned into the INSS, UIS or HRLMD systems.

## **RELATED PROJECTS**

INSS, UIS and HRLMD are ongoing projects funded by PMS EOD, ONR and NSW to develop diver based underwater navigation and sonar systems for detecting, marking and relocating mines and other objects in the VSW and SW environment.